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Abstract. This paper provides an overview of PhD activities in Denmark with regard to Software engineering. The number of doctoral students in Denmark has been growing rapidly within the past decade – especially within the area of science and technology. In the same period the PhD programmes have become more formalized. The paper describes the general framework for PhD studies in Denmark, and describes the major Danish providers of PhD studies in Software Engineering.

Keywords: PhD programmes , PhD programmes in Denmark, Software Engineering.

1 Introduction

Denmark has educations in software engineering both at bachelor and master levels. However, at the PhD level Software Engineering does not have its own programme in Denmark. Without being mentioned specifically Software Engineering is included in a number of doctoral programmes within ICT. This paper provides a condensed overview of the PhD educations in software engineering in Denmark with the purpose of identifying current and future trends. First the paper describes the historical background and the general framework for PhD educations in Denmark. Second the paper describes relevant PhD programmes offered at Danish Universities.

2 Doctoral programmes in Denmark

Until the 1980's the PhD education was not a well-established part of the Danish educational system. In most disciplines there were only few people with this degree outside the university sector. Even within the university sector most university professors did not have a PhD degree.

In the 1990's it became a requirement to have a PhD in order to qualify for an assistant professorship, and a more formal framework for the PhD education was devel-

oped. Before then, the only requirement was to prepare a dissertation, which had to be accepted and defended in front of the supervisor and one external examiner. PhD students with a busy supervisor were often left alone, and they received little supervision during their studies. This implied prolonged study times well beyond the three years and low completion rates.

In order to facilitate a continuing growth in the number of degrees awarded, a general framework more formal and unified rules for the PhD study was created. These rules are still in force today.

It was decided that PhD students during the three years of study that students in addition to the dissertation should attend 30 ECTS (equivalent to one semester) courses, and deliver 6 months of teaching. This leaves only 2 years for pure research.

The idea was to create a better interaction between PhD students and the faculty. Courses should ensure a common platform of knowledge among candidates within a specific discipline and facilitate their thesis work. The teaching obligation had a dual purpose: One was to strengthening the pedagogical aspect of the education as a researcher. Second this was also seen as a way to finance PhD activities. The teaching obligation may be substituted with other communication and dissemination activities. This will often be the case, if there at the hosting institute is a lack of relevant courses, where the student can contribute.

As a consequence of the reform a whole set of new PhD courses had to be developed. Before that, PhD students might attend a few seminars and conferences designed especially for PhD students. But the reform created a need for a sizable portfolio of new courses aimed for PhD students. A number of PhD schools were established (usually one for each faculty), and within each school a number of PhD programmes were set up (usually at the institute level).

PhD schools may offer a number of PhD courses of general interest in areas such as methodology, literature search etc., while the programmes offer courses on more specific subjects. This new structure implied a more formal division of PhD studies by research topics, as all PhD students had to be attached to specific PhD programme.

Finally a requirement for studies abroad was introduced. According to this requirement it became mandatory to spend at least three months at another research institute outside Denmark. The idea was to expose students to different cultures for research and to facilitate creation of international research networks.

In 2006 Agreement on Distribution of the Globalisation Fund was adopted by a broad majority of the Parliament with the objective to enhance the innovative capacity in Denmark by an increase in research funds [1]. The agreement had a strong focus on the PhD education, and the universities were required to increase their annual intake of PhD students to 2,400 compared to 1200 in 2003. The point of departure was a low level of PhD degrees awarded in Denmark compared to other countries. In 2003 168 degrees per 1 million inhabitants were awarded. This was the lowest figure in the Nordic countries, well below the EU average and far behind countries like Germany (295) and Sweden (272) [1].

In 2014 Denmark produced 378 PhD candidates per one million inhabitants and Denmark had closed the gap to other European countries. In comparison Germany,

Finland and Sweden produced 348, 369 and 372 PhD candidates per one million inhabitants [1].

Figures are not detailed out on specific PhD programmes, but the growth in the volume of PhD candidates has in particular been in technical disciplines such as science, medical science and engineering. The number of PhDs admitted in engineering has grown from 252 in 2003 to 570 in 2015 (table 1).

Table 1. PhDs admitted to Danish Universities by Faculty

	2003	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Humanistic	168	151	147	223	214	202	233	209	189	232	198	178
Social Science	334	352	348	492	553	633	711	634	589	621	595	626
Medical Science	292	429	486	481	555	597	747	673	694	821	807	725
Engineering	252	269	295	438	540	545	634	593	631	611	590	570
Total	1210	1389	1490	1876	2109	2253	2628	2413	2457	2609	2477	2310
Index year 2000=100	103	119	127	160	180	192	224	206	210	223	212	197

Source: [1]

3 PhD Programmes in Software Engineering

PhD programmes are offered by all universities in Denmark, but none of them has a programme only dedicated to software engineering only. Seven universities have PhD programmes within ICT, and it is possible to carry out a PhD study within software engineering at these seven universities even though software engineering is not mentioned explicit in the outline of the programmes. These universities are:

- University of Copenhagen (KU)
- Technical University of Denmark (TUD)
- Aalborg University (AAU)
- Aarhus University (AU)
- University of Southern Denmark (SDU)
- Roskilde University (RUC)
- IT University of Copenhagen (ITU)

In this paper we will shortly describe the programmes at KU, TUD, AAU, and AU, as these are the major providers of educations in software.

3.1 University of Copenhagen

University of Copenhagen is the largest university in Denmark and they have an extensive PhD programme with 1161 science students enrolled (2016). However only

a small fraction of these (38) are enrolled at IT departments [2]. While the gender distribution is fairly equal among doctoral science students only 5 out 38 students from the IT department are women. Some years ago almost all PhD science students came from Denmark, but today more than 50% come from abroad – mainly Europe. Most projects are co-funded with funds from the Danish Research Council and from EU. Very few PhDs are funded purely by university funds. 4% are industrial PhDs funded by private companies.

3.2 Technical University of Denmark

Technical University of Denmark has a population of 1456 PhD students mostly in technical disciplines. 43% of these have at least some collaboration with industrial partners [3]. DTU has 19 PhD schools one for each department. There are five schools in ICT hardware and software. In relation to software engineering the most relevant is the one at DTU Compute, which produce 30 graduates per year [4].

3.3 Aalborg University

Aalborg University has 849 PhD students distributed among five PhD schools (one for each faculty). More than half are part of the faculties for Engineering and IT and Design. Information technology belongs to the Technical Doctoral School of IT and Design. At this school all PhDs are dependent on external funding either from the EU, The Danish Research Council or external funded research projects, which include PhD activities. It is also possible to provide your own funding either from private means or from foreign universities or scholarship programmes. A number of students from developing countries use this opportunity.

3.4 Aarhus University

Aarhus University has 1845 PhD students enrolled. This includes 673 from science and technology. These are distributed among 31 different programmes at four graduate schools, 13 of these are in science and technology including 1 in computer science with 43 doctoral students enrolled. Looking at the list of research areas covered by the computer science programme, it seems that software engineering is poorly represented especially with regard to the interdisciplinary aspects. Focus is mainly on software development, algorithms, and user interaction [5].

4 Discussion

Denmark has experienced a high growth in the number of PhDs in Software engineering as well as in other technical disciplines. While the number of PhDs in social sciences and humanities have remained stable. This growth is the result of a deliberate policy with a high focus on doctoral students within IT and engineering. This growth

has been accommodated by a formalization of the curriculum for PhD studies. Today doctoral students have to follow a number of courses within specific areas.

These rules may help many students to be able to complete their studies within time, but impose also some restrictions on students.

Furthermore there is less freedom in the choice of subjects, as provision of external funding may be conditioned by research related to specific research topics. This is not only the case for industrial PhDs, but also for PhDs funded by various research programmes. The internal funds provided by universities have declined and are often tied to provision of additional funds from external sources. It can be expected that these trends in funding will favour more applied research with immediate relevance for private companies at the expense of more theoretical research topics. However, it has not been possible to document such trends.

The Danish PhD programme has become much more international within the past decade. This follows the general trend of internationalisation within the university sector, but it is also a result of the way funding is provided. This affects areas like software engineering, where the job market in private industry for many students are seen as a more attractive option.

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